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ACADEMY OF HEALTH SCIENCES
DEPARTMENT OF MEDICAL SCIENCES
PHYSICAL THERAPY BRANCH

Central Nervous System: The Spinal Cord (2 periods)

REFERENCES:

Noback, Strominger, Demarest.: The Human Nervous System. 5th ed. Williams and Wilkens, 1996.

Gertz, David S. Neuroanatomy Made Ridiculously Easy and Understandable. 5th ed. Aspen Publishers, Inc. Gaithersburg, Maryland. 1996.

Tortora GJ & Grabowski, S.R. Principles of Anatomy and Physiology. 9th ed. New York: Harper and Row, 2000.

Objectives:

1. Terminal Learning Objective. Given a list, select the anatomic features and functions of the spinal cord IAW Noback et al, Gertz, and Tortora.

2. Enabling Learning Objectives:

   a. Given several statements about the general information of the spinal cord, choose which statements are correct and which are incorrect IAW Noback et al, Gertz, and Tortora.

   b. Given a diagram, identify the dorsal horn, lateral horn, ventral horn, dorsal root, ventral root, dorsal root ganglion, and spinal nerve IAW Noback et al, Gertz, and Tortora.

   c. Given several statements, select the correct statements describing gray and white matter of the spinal cord, ventral roots, dorsal roots and spinal nerves IAW Noback et al, Gertz, and Tortora.

   d. Given several statements about the lateral spinothalamic tract and the corticospinal tract, select those statements which correctly describe their entire pathway, locations of synapses, location of crossing to the contralateral side and their function IAW Noback et al, Gertz, and Tortora.

NOTES

A. General Information:

1. The spinal cord is a continuation of the neural tissue in the **medulla oblongata** which exits the cranium through the **foramen magnum**.

2. The spinal cord lies in the vertebral canal from the **C1** vertebrae to approximately the **L2** vertebrae in the adult.

3. At the inferior end of the spinal cord there is a bundle of nerve roots which travel inferiorly from the spinal cord through the vertebral canal to their exit point (intervertebral foramen) and into the periphery. This bundle of nerve roots is the **cauda equina** (horse tail).

4. The **meninges** which surround the brain are continuous with those that surround the spinal cord. Additionally the **cerebrospinal fluid** is continuous in its flow around the brain and the spinal cord.

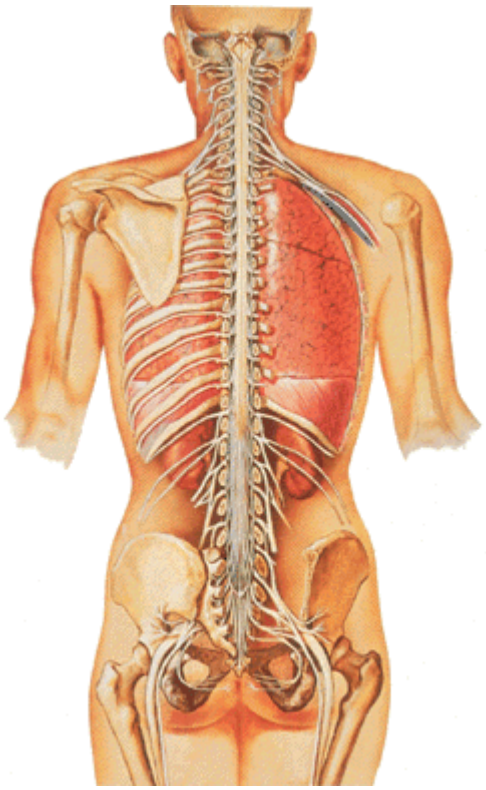
    a. The outer-most meninge is the **dura mater** which lies inferior to the vertebrae and a layer of fat.

    b. The middle layer of meninge is the **arachnoid**. The arachnoid layer has web-like extensions to the inner-most layer, the pia mater. **Cerebrospinal fluid** flows between the arachnoid and pia mater within the arachnoid extensions.

    c. The inner-most meninge is the **pia mater** which lies directly on the spinal cord.

    d. Clinical importance: The space between the vertebrae and the dura mater where fat is located is the site of **epidural injections**. The space between the arachnoid and the pia mater where cerebrospinal fluid is located in the site of **spinal taps**.

5. **Thirty-one** pairs of spinal nerves come off of the spinal cord. These nerves are part of the peripheral nervous system.



B. Gross anatomy:

1. **Gray matter**:

a. Central region of the spinal cord.

b. Contains the synapses and cell bodies of neurons.

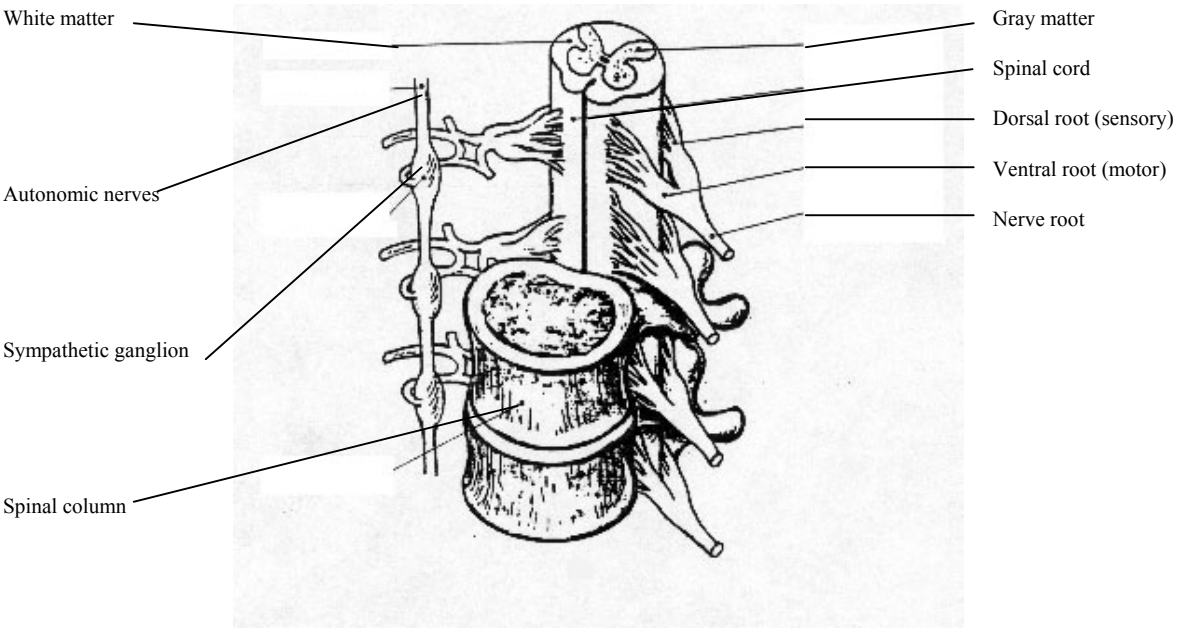
c. The gray matter is symmetrical left to right.

d. There are different functional regions of the gray matter:

1) **Dorsal (posterior) horn** - sensory

2) **Ventral (anterior) horn** - motor

3) **Lateral horn** - autonomic neuron cell body location, only found in the thoracic & upper lumbar (sympathetic) and sacral (parasympathetic) segments.



2. **White matter**:

   a. Area surrounding the gray matter.

   b. Contains the myelinated axons carrying information from the brain to the spinal cord (motor), and from the spinal cord to the brain (sensory).

   c. There are different functional regions of the white matter:

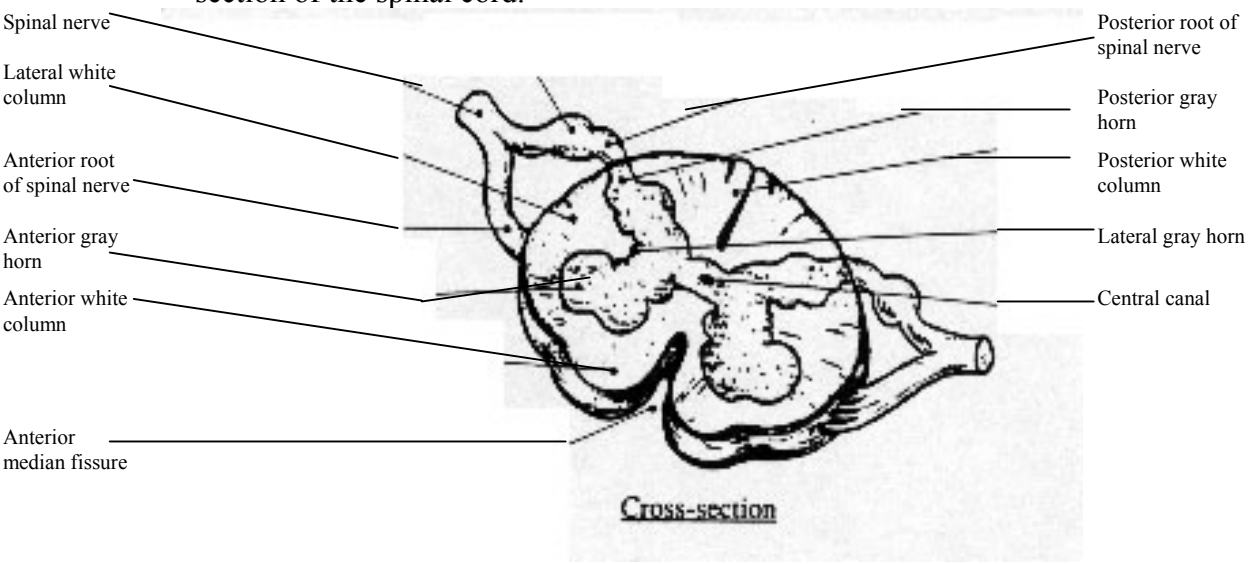
      1) **Posterior (dorsal) column** - carries sensory information about vibration, proprioception, and discriminated touch.

      2) **Lateral column** - carries sensory information about pain, temperature and crude touch as well as voluntary motor information.

      3) **Anterior column** - carries sensory information about pain, temperature and crude touch as well as involuntary (coordination) motor information.

   d. The columns have different **tracts** (fasciculus, funiculi, lemnisci or peduncles) of axons that carry the same specific type of information and all run together. There are tracts carrying only voluntary motor and tracts carrying only accessory/coordination motor. These tracts can be precisely located on a cross

section of the spinal cord.



3. **Dorsal (posterior) root**:

   a. Contains the axons of all **afferent** neurons, somatic and autonomic, that are entering the spinal cord at that level.

   b. The **dorsal root ganglion** is a swelling in the dorsal root that contains the **cell bodies** for the afferent neurons.

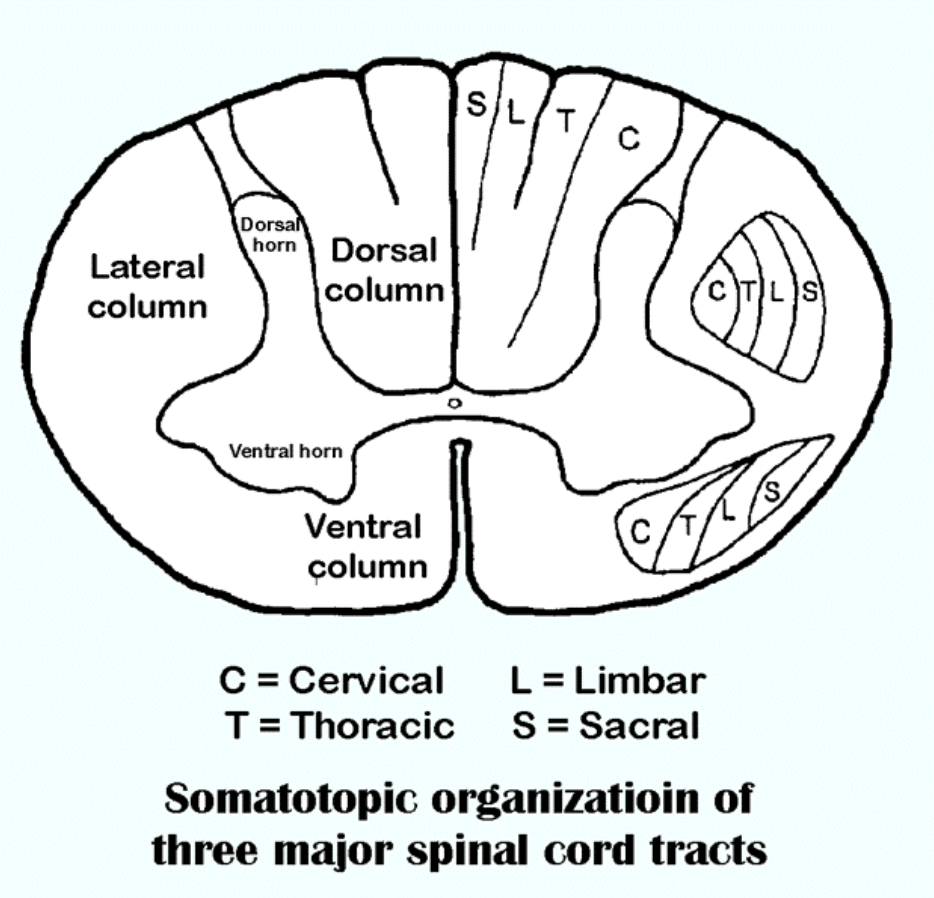
NOTE: Afferent neurons are different from the typical neuron in that they have **one main dendrite** which carries the information from the receptor (tip of the dendrite) to the cell body located in the dorsal root ganglion. They also have one main axon which takes the information from the cell body to the spinal cord. The dendrite and the axon join together near the cell body to form a **stalk** which leads to and from the cell body.

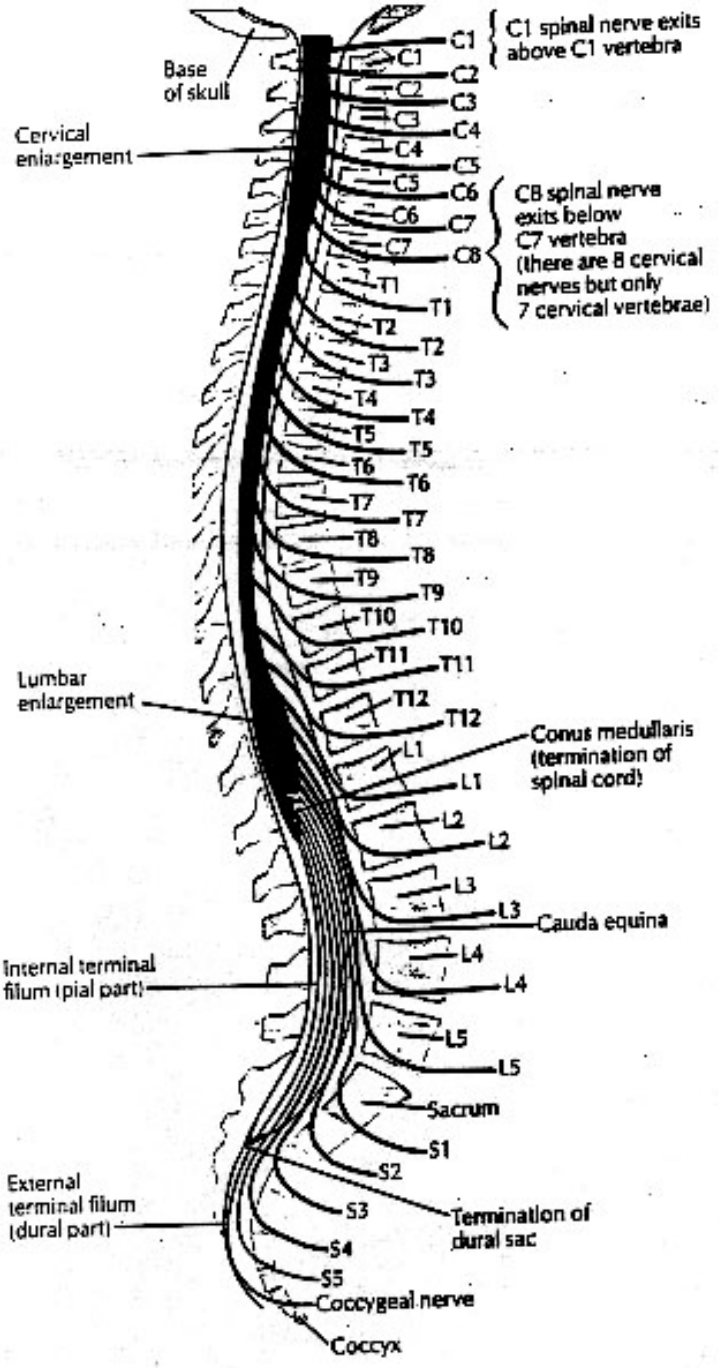
4. **Ventral root**: Contains the axons of all efferent neurons, somatic and autonomic, that are exiting the spinal cord at that level.

5. **Spinal nerve**:

a. Formed by the union of the dorsal roots and the ventral roots as they go through the intervertebral foramen.

b. Named according to the level of the vertebrae that composes the inferior portion of the intervertebral foramen in the cervical region, and by the vertebrae that composes the superior portion of the intervertebral foramen in the rest of the spinal column. Notice that although there is no vertebrae C8 but there is a spinal nerve C8.




C1 spinal nerve exits above C1 vertebra
Base of skull
Cervical enlargement
C8 spinal nerve exits below C7 vertebra (there are 8 cervical nerves but only 7 cervical vertebrae)
Lumbar enlargement
Conus medullaris (termination of spinal cord)
Cauda equina
Internal terminal filum (pial part)
Sacrum
External terminal filum (dural part)
Termination of dural sac
Coccygeal nerve
Coccyx

C. Central nervous system tracts:

1. Lateral spinothalamic tract

a. Carries sensory information from the spinal cord to the thalamus & cerebrum.

b. Specific for **pain & temperature** sensations.

c. Anatomical pathway: **Three neuron pathway**

1) **First order neuron**: (Afferent neuron)

a) Dendrite has free nerve ending receptors.

b) Dendrite sends the sensory information to the cell body in the dorsal root ganglion.

c) Axon carries the information from the cell body through the dorsal root to the dorsal horn in the spinal cord.

d) Synapses onto the second order neuron in the **dorsal horn** at the spinal cord level of entry.

2) The **second order neuron**: (internuncial neuron)

a) Dendrites and cell body located in the dorsal horn of the spinal column.

b) Axon immediately **crosses** to the opposite side of the spinal cord and then ascends in the lateral spinothalamic tract to the thalamus.

c) Synapses onto the third order neuron in the **thalamus**.

3) The **third order neuron**: (Internuncial neuron)

a) Dendrites and cell body located in the thalamus.

b) Axon ascends through the internal capsule to the **postcentral gyrus** of the parietal lobe for integration.

d. Clinical disorders:

1) Lesions which include only the left or the right spinothalamic tract, thalamus or cerebral hemisphere will result in sensory deficit on the **contralateral** side of the body.

2) Lesions which include only the afferent neuron, first neuron of the pathway, will result in sensory deficit on the **ipsilateral** side of the body.

3) **Phantom pain**:

a) After amputation the patient occasionally reports sensations coming from the now amputated limb. For example, a foot amputation patient complains of painful toes.

b) The sensation is produced by the swelling and scar tissue at the amputation site which places pressure on the peripheral nerve containing those neurons that previously supplied sensory information from the amputated limb. The pressure on the nerve produces an action potential which sends a sensory impulse to the brain. The brain interprets the impulse as a pain or temperature sensation from the extremity despite the brain's understanding the extremity is no longer there.

2. **Posterior column**: Fasciculus gracilis & fasciculus cuneatus

a. Carries sensory information from the spinal cord to the cerebrum.

b. Specific for the sensations of **proprioception, fine touch and vibration**.

c. Fasciculus gracilis carries information from the lower half of the body and fasciculus cuneatus carries information from the upper half of the body.

3. **Corticospinal tract:**

a. Carries motor information from the cerebral cortex to the spinal cord.

b. Specific for voluntary motor.

c. Anatomical pathway: Two neuron pathway - **Upper & Lower motor neuron**

1) **Upper motor neuron**: (internuncial neuron)

a) Cell body and dendrites located in the **precentral gyrus** of the frontal lobe.

b) Axon descends through the internal capsule to the medulla oblongata.

c) Axon crosses to the **contralateral** side of the **medulla oblongata** and then continues to descend into the spinal cord.

d) Synapses onto the lower motor neuron in the **ventral horn** of the spinal cord at the level of exit.

2) **Lower motor neuron**: (efferent neuron)

a) Cell body and dendrites in the ventral horn of the spinal cord at the level of exit.

b) Axon exits the spinal cord through the **ventral root** and goes to its effector **muscle**.

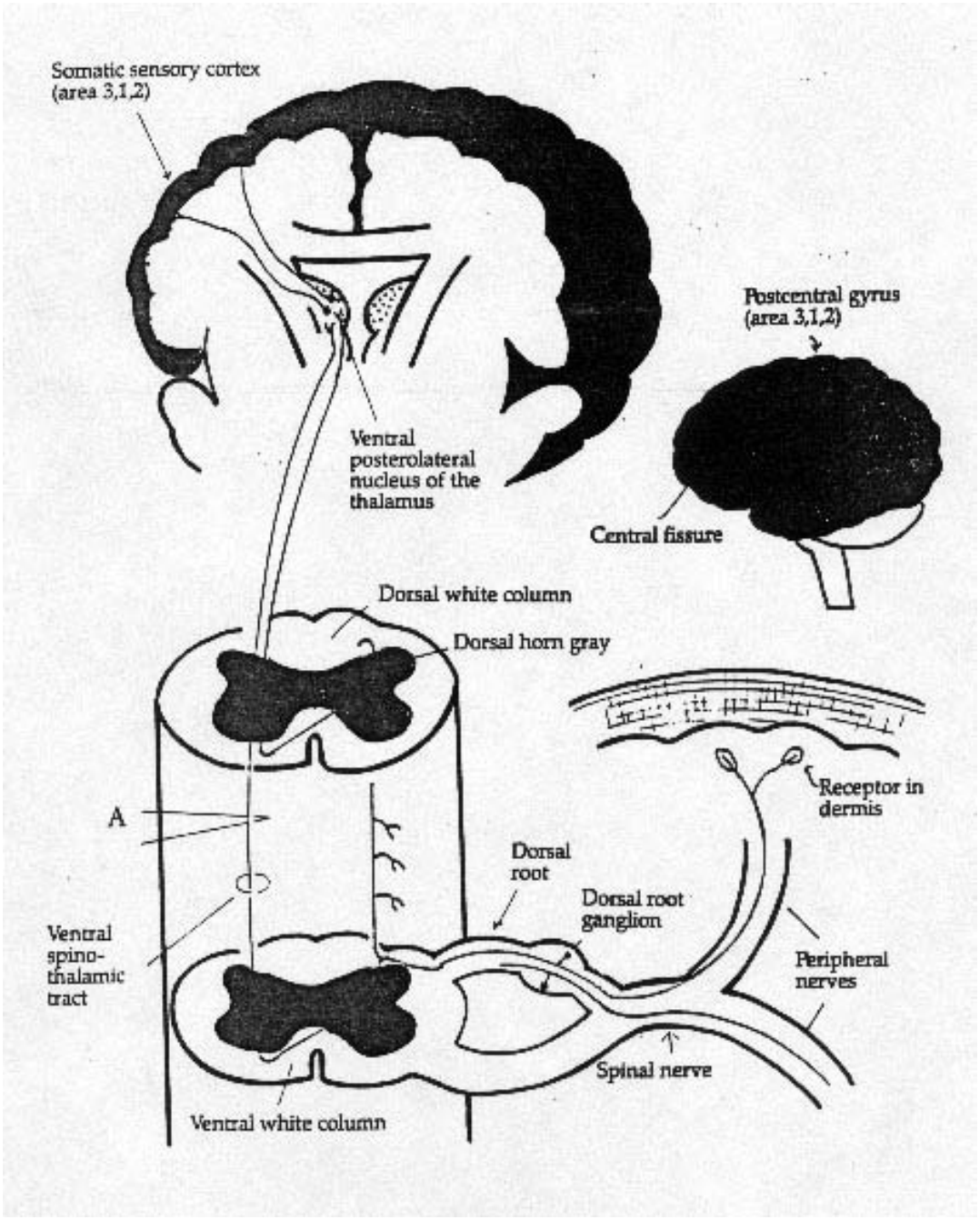
d. Clinical disorders:

1) Lesions superior to the medulla oblongata will result in motor deficit **contralateral** to the lesion.

2) Lesions inferior to the medulla oblongata will result in motor deficit **ipsilateral** to the lesion.

3) Lesions of the upper motor neuron result in different characteristics that those of the lower motor neuron. The difference is mainly do the ability for **reflexes** to continue without any suppression in upper motor neuron lesions, while in lower motor neuron lesions the reflex arc is completely disrupted.

4. There are many other pathways or tracts within the spinal cord. The above is a sampling of some of the most commonly referred to tracts in physical therapy.


Somatic sensory cortex
(area 3,1,2)
Postcentral gyrus
(area 3,1,2)
Ventral
posterolateral
nucleus of the
thalamus
Central fissure
Dorsal white column
Dorsal horn gray
Receptor in
dermis
A
Dorsal
root
Dorsal root
ganglion
Ventral
spino-
thalamic
tract
Peripheral
nerves
Spinal nerve
Ventral white column

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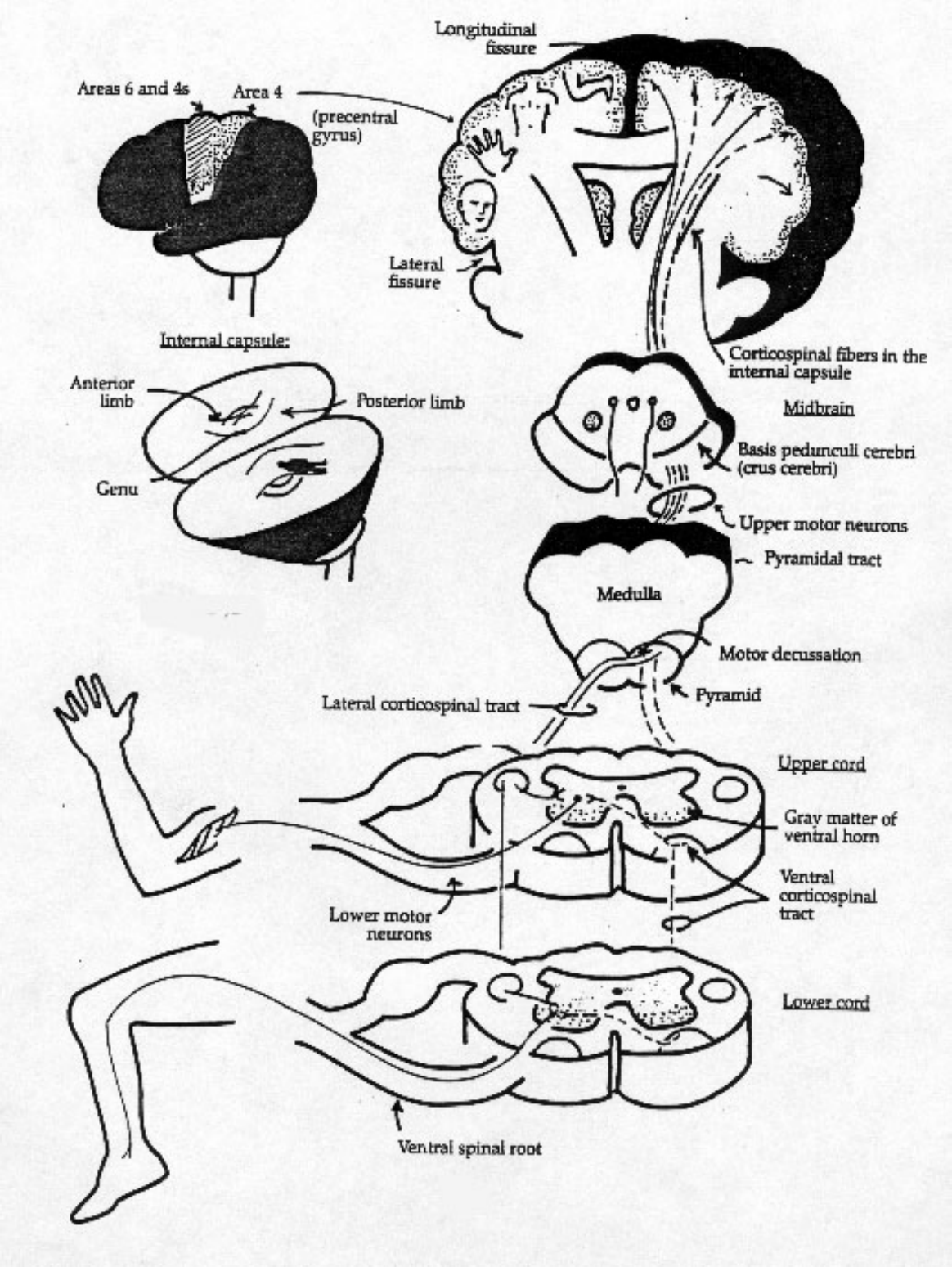

WORKSHEET

Central Nervous System: The Spinal Cord

Objective a:

Discuss the following:

1. Levels of the spinal cord:

2. Cauda Equina:

3. Meninges- layers and function:

4. CSF:

5. Number of Spinal Nerves:

Objective b.

State the function of each region below:

1. Dorsal horn _____
2. Ventral horn _____
3. Lateral horn _____
4. Posterior column _____
5. Lateral column _____
6. Anterior column _____

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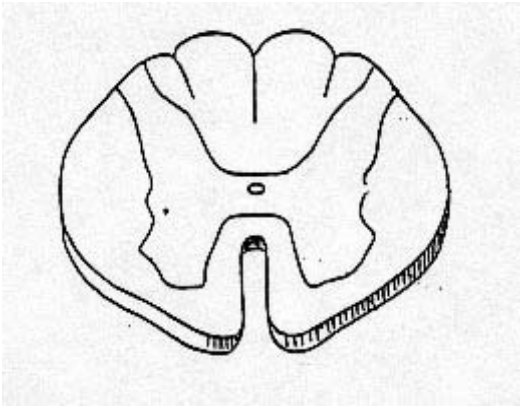
Label each of the above six regions on the following diagram:

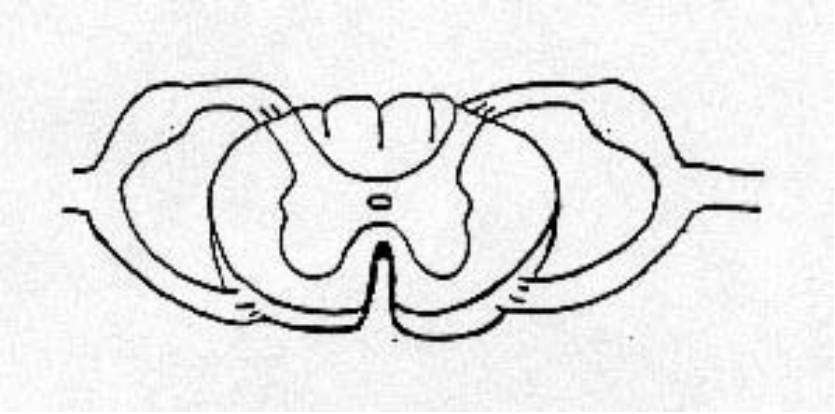


Objective c:

State the function of each:

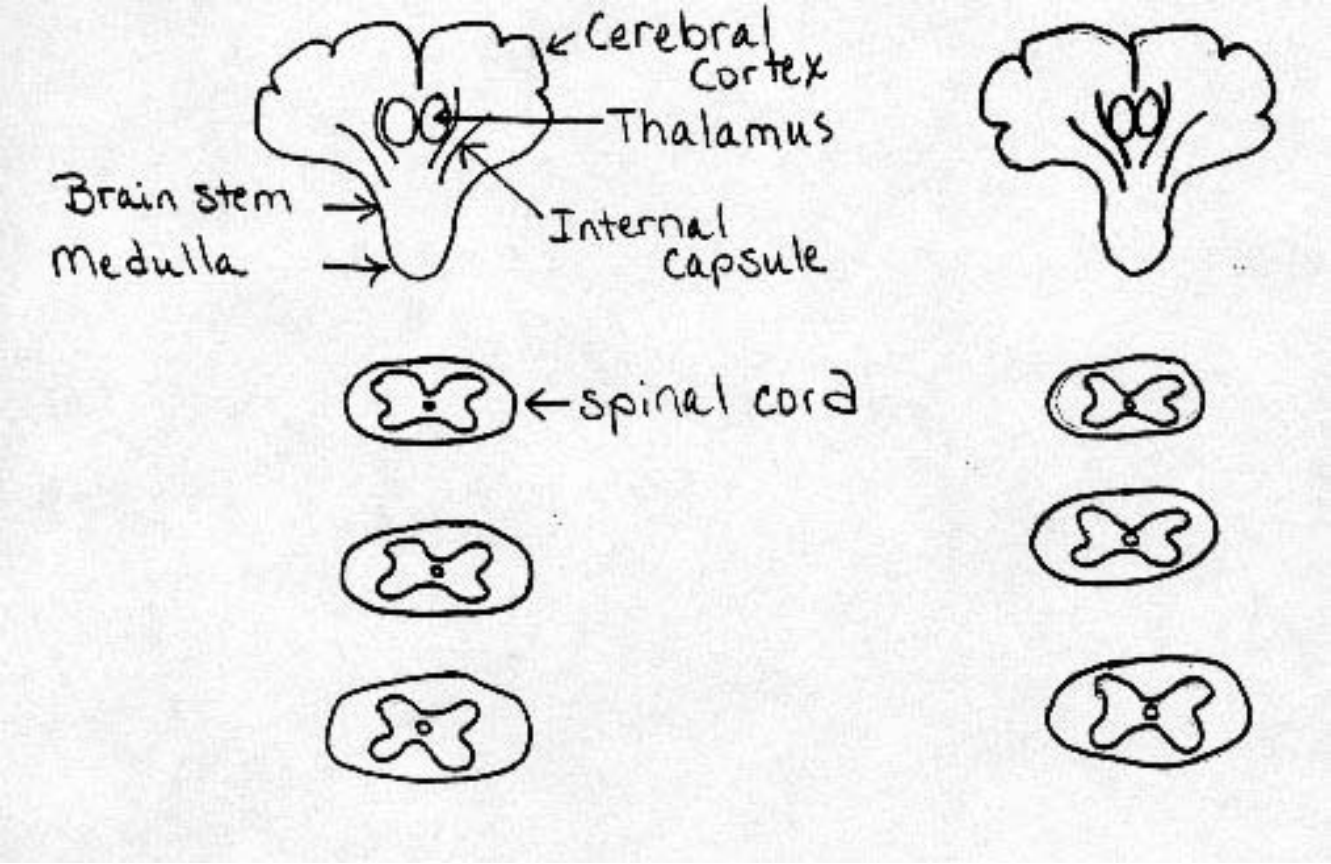
1. Dorsal root _____
2. Dorsal root ganglion _____
3. Ventral root _____
4. Spinal nerve _____

Label the above four items on the below diagram:



Objective d:

Draw the lateral spinothalamic tract & the corticospinal tract into the below diagrams of spinal cords, brainstems and brains. Draw the individual neurons, their cell bodies and the synapses.



Lateral Spinothalamic Tract **Corticospinal Tract**